

# **CONSTELLATION X-RAY MISSION AND SUPPORT**

**NASA Cooperative Agreement NCC5-368**

**Supplement to the Third Annual Report**

**For the Period August 1, 2001 to January 10, 2002**

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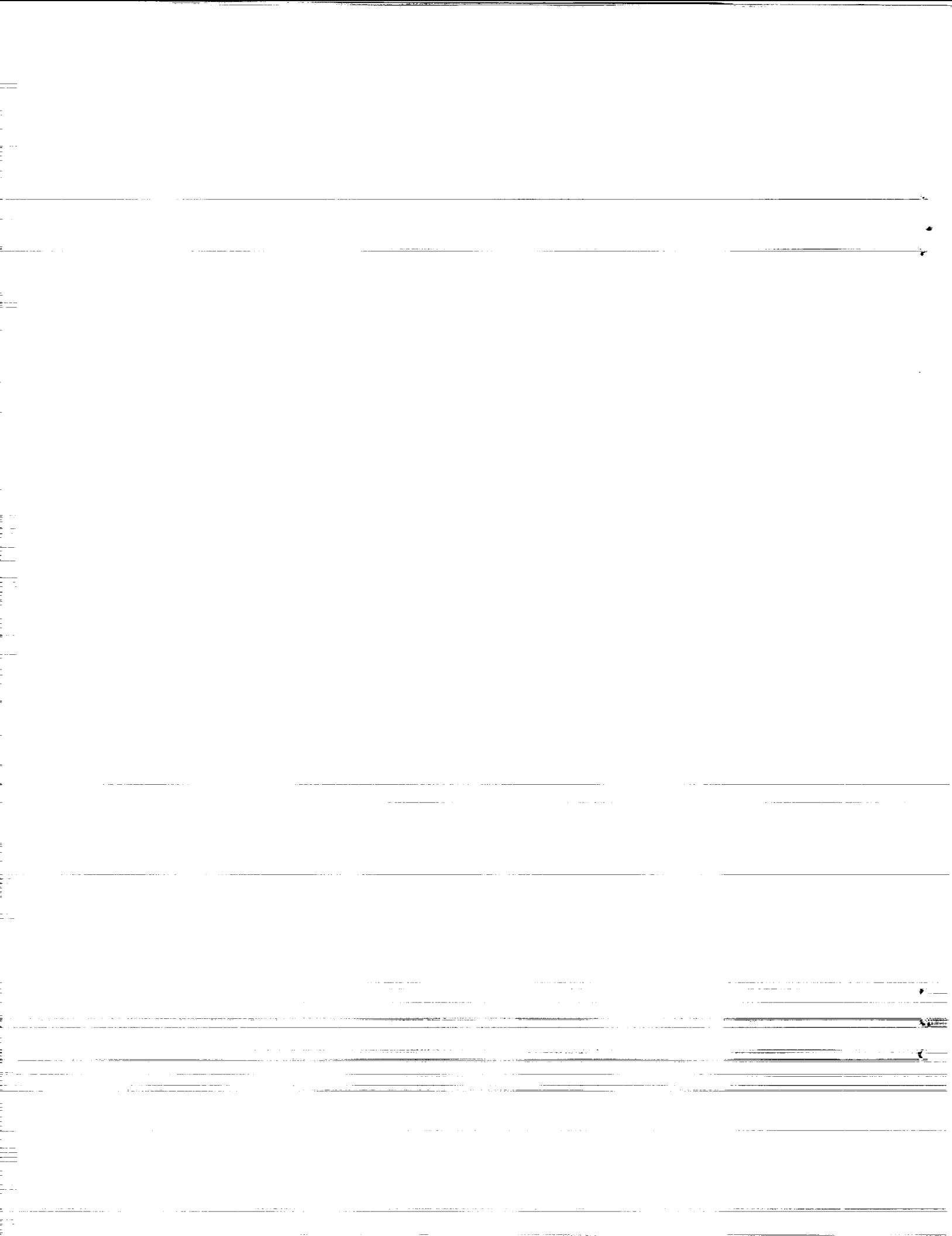
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**The Smithsonian Astrophysical Observatory  
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## **1.0 Introduction**

This report is a supplement to the Third Annual Report summarizing work performed by the Smithsonian Astrophysical Observatory (SAO) for NASA Goddard Space Flight Center (GSFC) under Cooperative Agreement NCC5-368<sup>1</sup>. The Agreement is entitled "Constellation X-ray Mission Study and Support." This supplementary report covers the period from October 1, 2001 through January 10, 2002. The report has been prepared and submitted to ensure that the Constellation-X Project Office at GSFC has current performance information needed to evaluate a proposed modified budget for FY02. That proposed budget is being submitted separately.

SAO continues to perform work under the overall direction of Dr. Harvey Tananbaum, the SAO Principal Investigator for the program. Mr. Robert Rasche is the SAO Program Manager and is responsible for day-to-day program management at SAO and coordination with GSFC.

The report summarizes the main areas of SAO activity. Most of the work has been done jointly with personnel from GSFC and Marshall Space Flight Center (MSFC). We describe SAO participation in these efforts.

As is appropriate to a Cooperative Agreement, SAO continued to work with GSFC in an integrated team mode. SAO was involved in the overall mission management, technology development, scientific direction, and mission definition. Figure 1 summarizes the project organization. While formal overall management responsibility resides with GSFC, scientific lead and subordinate responsibilities continue to be shared by GSFC and SAO.

The work performed by SAO is consistent with the SAO proposal "Constellation X-ray Mission Study and Optics Development" dated September 1997, which was the basis for establishing the subsequent Cooperative Agreement. Over time, the scope of the effort has expanded somewhat to accommodate the needs of the project. Work, except for meeting support and high priority program tasks, has been at a level of effort. Priorities and work progress have been closely coordinated with the Constellation-X Project Formulation Manager at GSFC. Funding limitations constrained the work accomplished during this period.

Nonetheless, a significant amount of work was accomplished. Under the Agreement, SAO performed work in seven major areas of activity. These areas related to:

- Constellation X-ray Mission Facility Definition Team and Study Management
- Science Support
- Spectroscopy X-ray Telescope (SXT)
- Systems Engineering
- Travel in Support of the Work Effort
- In-house Management and Coordination

The following sections summarize work performed by SAO during the reporting period.

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<sup>1</sup> In subsequent text, NCC5-368 is simply referred to as the "Agreement". A Cooperative Agreement is the appropriate vehicle for the close, flexible, and wide ranging interaction between SAO and NASA needed to ensure the success of the Constellation-X project formulation activity.

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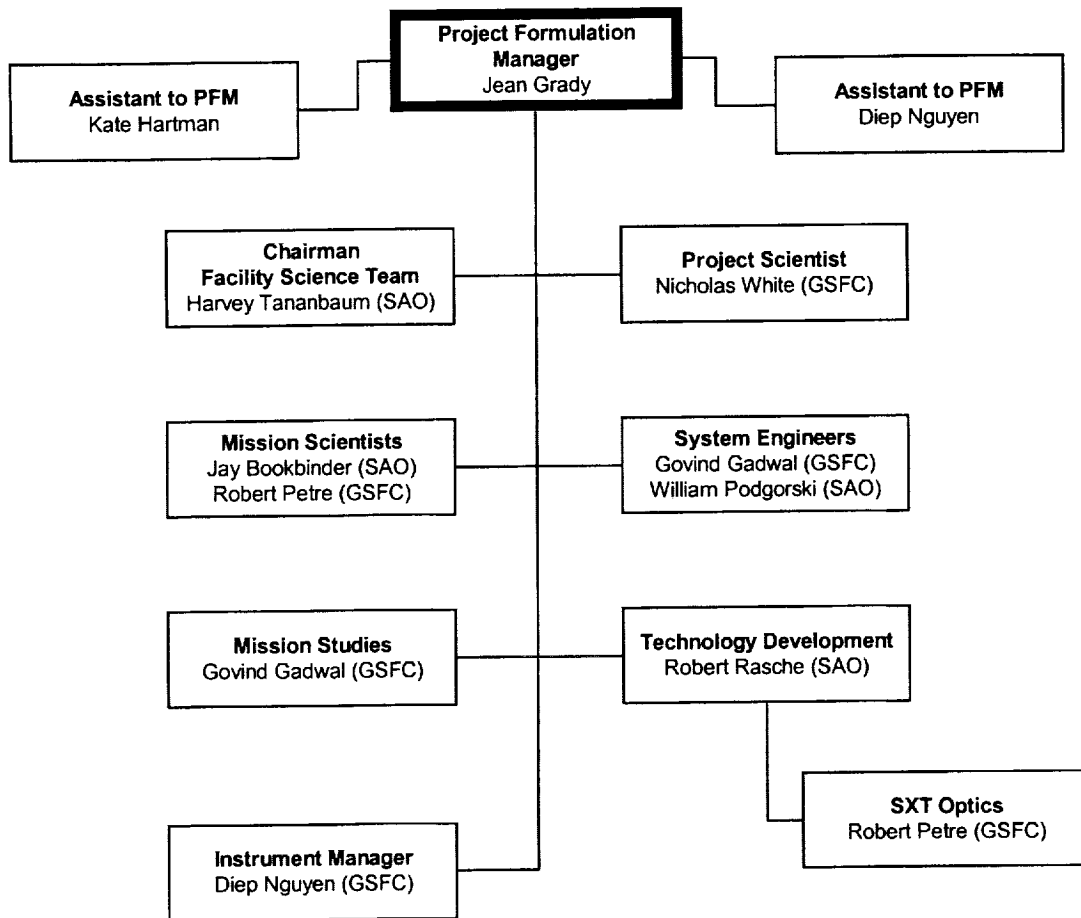


Figure 1

# Constellation-X

Project Organization Chart

## **2.0 Constellation X-ray Mission Definition Team and Study Management**

### **2.1 General Study Management and Coordination**

SAO continued to be heavily involved in Constellation-X mission definition and the overall management of the study. Management decisions generally involved the Project Scientist, Dr. Nicholas White (GSFC), the Facility Science Team Chairman, Dr. Harvey Tananbaum (SAO)<sup>2</sup>, the Project Formulation Manager, Ms. Jean Grady (GSFC), and the SAO Program Manager, Mr. Robert Rasche. Frequently the two Mission scientists, Dr. Jay Bookbinder (SAO) and Dr. Robert Petre (GSFC) were also involved.

SAO participated heavily in the technical overview, planning, and review of both future work and work in progress with particular emphasis on the SXT Mirror Assembly and its related Optical Assembly Pathfinder, Engineering Unit, and Prototype assemblies.

SAO continued to be involved in the management of mission definition activities, particularly with regard to thermal control, error budget development, and developing both mission requirements and resultant flow-down requirements. SAO personnel brought extensive and relevant experience from CHANDRA, HEAO, TRACE, HST, and other programs to the Constellation-X mission definition work.

Drs. White and Tananbaum had primary responsibility for scientific management with support from Drs. Bookbinder (SAO), Weaver (GSFC), and Petre (GSFC) and, occasionally, others. This included coordination with members of the Facility Science Team, interactions with NASA Headquarters and the scientific community at large, as well as participation in the Constellation-X Study Team meetings that were held approximately every two weeks at GSFC. Other special meetings were also supported.

The SAO management team participated aggressively in establishing plans, budgets, presentations, and priorities. This has been and continues to be an on-going and more or less continuous activity.

### **2.2 Technology Development Management and Coordination**

Under the Agreement, SAO has an important role in managing and coordinating technology development for Constellation-X. That role continued through the reporting period. The organization chart on page 2 shows Mr. Rasche responsible for coordinating technology development. He has been supported by other SAO staff and, of course, works closely with both GSFC and MSFC staff.

Sao's main management involvement has been related to the SXT X-ray mirror. However, SAO, particularly Rasche, has kept involved with and informed of instrument technology developments and related planning and budget negotiation. During the period, plans were submitted by each of the IPT leaders who subsequently participated in intensive reviews of their plans and proposed budgets. Diep Nguyen and Kate Hartman at GSFC are heavily involved with the instruments and are handle the day-to-day interfaces. Since the IPT funding comes through GSFC contracts (soon to be grants), the SAO role has been primarily to provide expertise, coordination, and general overview to the instrument development work. With few exceptions, SAO supports all project teleconferences related to instrument technology.

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<sup>2</sup> Because Constellation-X is a consolidation of their individually proposed and accepted programs into a single program, Drs. White and Tananbaum function as equal Co-Principal Investigators although they have well-defined and separate formal responsibilities.

During the reporting period, a meeting was held at SAO with Dr. Webster Cash to discuss both technical and programmatic issues related to the "off-plane" grating concept.

### **2.3 Reports and Presentations**

SAO personnel developed and made presentations at many meetings. These meetings included the biweekly team meetings at GSFC, and related splinter meetings, as well as technical interchange meetings (TIMs). The TIMs have generally been related to work on the SXT Optical Assembly Pathfinder.

### **2.4 Mission Studies**

SAO personnel also made direct technical contributions to the ongoing mission studies at GSFC and to discussions and trades related to mission operations and instrument accommodation. This helps ensure that relevant CHANDRA (AXAF) experience (which is ongoing) in these areas is transferred to the Constellation-X program in an effective and continuous way. These contributions have tended to be related to systems engineering issues — an SAO strength (see Section 5).

### **3.0 Science Support**

#### **3.1 Chair of the Facility Science Team (FST)**

Under the Agreement, SAO provided and continues to provide the Chair of the Constellation-X Facility Science Team, the group of scientists who help guide the program with regard to scientific objectives and needed capabilities. Dr. Tananbaum serves as Chair and is assisted by the Mission Scientist, Dr. Bookbinder and other members of the FST from several institutions and, of course, the Project Scientist, Dr. White and his science colleagues at GSFC.

During the period of performance, Dr. Tananbaum was a point of contact for both general FST members as well as for the leaders of the instrument technology teams. This activity was closely coordinated with Dr. White at GSFC who carried out a similar function. In general, Dr. White was more involved with the Government members of the FST and Dr. Tananbaum worked with FST members from non-Government organizations.

#### **3.2 Mission Scientist**

As required by the Agreement, SAO provided the expert services of Dr. Jay Bookbinder who filled the position of the Mission Scientist from SAO. His GSFC counterpart is Dr. Robert Petre.

Dr. Bookbinder participated in team meetings at GSFC and SAO and was an active and direct technical contributor to the SAO team. He also carried out special assignments for the FST Chair, Dr. Tananbaum. Dr. Bookbinder brought substantial and relevant expertise and experience from TRACE and other NASA programs. Working with others, he continued to further define and document the Constellation-X Top Level Requirements. A significant amount of both analysis and coordination with others was required to carry out this activity.

#### **3.3 Representation at Various Scientific Meetings**

Drs. Tananbaum and Bookbinder attended and participated in scientific and advisory committee meetings during the period. Their participation at these events helped to promote the Constellation-X program by providing information about the program, answering questions, and soliciting inputs to help ensure a balanced, effective, and significant science program.

#### **3.4 Facility Science Team Meeting**

A meeting of the FST was held at GSFC (off site) on November 15-16, 2001. May 3-4, 2001. The meeting was organized under the direction of Dr. Tananbaum. Scientific, programmatic, and technical issues were covered at the meeting. Emerging *Chandra* results were presented that clearly show the scientific need for Constellation-X.



## **4.0 Spectroscopy X-ray Telescope (SXT)**

During the reporting period, more SAO effort was applied to the Spectroscopy X-ray Telescope and, in particular, to its X-ray mirror<sup>3</sup> than to any other task. SAO performed SXT related work in six main areas:

1. SXT Management and Coordination
2. SXT Mirror Module Design
3. SXT Mirror Assembly and Alignment Studies
4. SXT Error Budget Development
5. Segment Mirror Mandrel Procurement
6. Flight Mirror Development Planning

### **4.1 SXT Management and Coordination**

Working with the concurrence of the Project Formulation Manager at GSFC (Jean Grady), SAO provided extensive oversight and direction to the Constellation-X SXT mirror definition and development. This activity included but was not limited to:

- Participation in numerous status review and planning teleconferences
- Informal tracking of SXT work progress at MSFC, GSFC, and SAO
- Evaluation and informal reporting of progress to GSFC Constellation-X project office.
- Development and evaluation of work plans and budgets
- Formulation and presentation of recommendations for future plans and priorities
- General overview of SXT work

An SXT Technology Roadmap was started. This is a joint effort between SAO and GSFC to produce a document to describe our program for developing and demonstrating the ensemble of activities that make up the SXT technology program.

### **4.2 SXT Mirror Module Design**

SAO continued in-house concept and analysis studies related to SXT segmented mirror concepts, and, in particular, the OAP and the engineering and prototype units that will follow it. William Davis (SAO) has provided essentially all of the precision structural analysis support to the ongoing work. In this role, Davis works closely with his GSFC counterparts and participates in telephone conferences and on site meetings at GSFC.

As work on the OAP and subsequent designs has begun, SAO has started to track and evaluate the work as it progresses. This effort provides independent assessments and recommendations to the Project Formulation Manager, Jean Grady.

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<sup>3</sup> Technically the term Spectroscopy X-ray Telescope refers to the complete X-ray telescope. In practice, the term SXT and SXT Mirror have, unfortunately, come to be used interchangeably. The greater portion of SAO activity related to the SXT was directed at the X-ray mirrors per se.

#### 4.3 SXT Mirror Assembly and Alignment Studies

SAO contracted with Bauer Associates to evaluate if and how the *Chandra* Centroid Detector Assembly (CDA) could be used to align and/or study the Constellation-X mirror systems starting with the OAP. Paul Glenn who developed the CDA for the *Chandra* program is performing most of this work.

SAO continued to work at a low level of effort on a detailed baseline plan for the SXT Flight Mirror Assembly development. The plan begins with current work now being done on an Engineering Model segmented mirror and continues through the delivery and integration of the flight mirror assemblies. Effort to date has concentrated on identifying tasks and task sequences and the relationships of these to each other. We also started to revisit cost estimates.

#### 4.4 SXT Error Budget Development

Work on the SXT error budget continued during the reporting period although because of both personnel and funding conflicts, the effort was somewhat limited. Nonetheless, substantial progress was made. This was facilitated by the close working relationship that has now developed between Drs. Podgorski (SAO) and Dr. Saha (GSFC) who are both involved in the development of the error budget. They have tended to take different approaches which when their analyses produce equivalent results (which they usually do) provides an important check on the work as a whole.

#### 4.5 Segmented Mirror Mandrel Procurement

During August, a flight sized (1.6 m diameter, 10 m focal length) segment mandrel was finally ordered from Carl Zeiss. SAO participated in the selection process and in all subsequent reviews of progress and documentation. MSFC is managing the Zeiss contract.

#### 4.6 SXT Flight Mirror Program Planning

Useful SXT mirror technology will almost certainly be constrained by at least four factors related to flight mirror development rather than mirror technology per se. These factors are:

- Availability of required infrastructure and expertise
- Ability to obtain required infrastructure where none exists
- Corporate willingness to accept a contract for large flight or even prototype mandrels, particularly when compared with other business opportunities.
- Technical concerns related to size and mass (mainly a full shell concern)

Working with Dr. Zhang (GSFC) and others, Rasche (SAO) is considering some of the above issues in the context of segmented mirrors and the necessary forming and finish mandrels. Upon selection of Carl Zeiss for a flight segment mandrel and subsequent contract award (with follow on options), a dialog was initiated. In December, Rasche visited both Zeiss and Schott (providing the rough mandrel blank to Zeiss), viewed the mandrel currently being made, and discussed our potential flight program in detail. The visit was highly successful. Because much of the discussion was competition sensitive, it will not be reported here.

## **5.0 Systems Engineering**

SAO continued to provide systems engineering support to the Constellation-X project. Work was mainly concentrated in five areas:

- Thermal control
- Requirements and requirements flow down development
- Opto-structural analysis of segmented SXT concepts
- System error budgets

### **5.1 Thermal Control**

SAO and GSFC continued to work together in the areas of both instrument and overall system thermal control. In particular, David Boyd and Mark Freeman at SAO and Wes Ousley at GSFC have continued to review the system as it develops and coordinate closely with each other. Effort by SAO in this area was limited primarily by available funding. SAO continued work related to SXT Mirror Assembly temperature control and has now developed power and temperature control envelopes as a function of thermal precollimator concepts.

### **5.2 Requirements and Requirements Flowdown**

The Constellation-X Top Level Requirements have been defined although a few of them may be modified. Recent work continues to focus on flow down requirements on the various Constellation-X subsystems. This work is being done primarily by Drs. Bookbinder and Podgorski with the participation and review of others as appropriate. This work included analysis and research related to establishing numerical values for the various requirements.

### **5.3 Opto-Structural Analysis of Segmented SXT Concepts**

As indicated in Section 4.2 provided optical and structural analysis support to the emerging SXT Engineering Unit effort. In addition, much of the relevant past documentation related to designs, assembly and alignment schemes was distributed to everyone at GSFC, MSFC, and SAO who might have an interest in the SXT Engineering Unit. The intent of this distribution was to a.) provide a reference, b.) identify issues that need to be considered in any design, and c.) present an approach that seems (perhaps with tweaking) to have merit and to make certain that people on the program would have no excuse for not having seen any of the subject material.

### **5.4 System Error Budgets**

Some, but not much work was done during the reporting period to extend system error budgets. That more work was not done in this area was due mainly to funding limitations. This important activity will receive much more attention in the coming year, particularly those components associated with both the full shell and segmented SXT mirror assembly design concepts.

## **6.0 Travel**

The Agreement provided funding for frequent program travel. Most of the travel was between SAO and either GSFC or MSFC.

With few exceptions, a Constellation-X Study Team meeting was held at GSFC every other week between 1:00 p.m. and 3:00 p.m. with splinter meetings on either side of this fixed time. This arrangement allowed SAO personnel to travel from Boston to GSFC and return on the same day with substantial savings in lodging and per diem costs. These meetings were usually attended by at least two SAO persons and occasionally by three or four if required by either the meeting agenda or related splinter meetings. Whenever possible, splinter meetings were set up on the same day as the team meetings. These meetings were usually technical interchange meetings that took the form of informal working meetings. However, some of the splinter meetings were management review and planning meetings.

When appropriate, Rasche visited GSFC for two days, one day for the Study Team Meeting and related splinters and the second day (either before or after) for informal management discussions with Jean Grady and others. This has worked quite well and will be continued over the coming year. Other SAO personnel generally have made a one-day trip to support the Study Team Meeting and sometimes related splinter meetings.

SAO staff working on SXT mirror technology traveled to MSFC. These trips related to segment mandrel procurement. Additional travel was required by SAO engineers to meet at GSFC relative to segmented mirror work.

## **7.0 In-House Management and Coordination**

In addition to the direct participation in the Constellation-X project summarized above, SAO carried out housekeeping, coordination, and planning activities at SAO. This work related to the orderly operation of the SAO Constellation-X team.

These activities included:

- Cost planning, tracking, analysis, and control
- Personnel evaluation inputs
- Purchasing and logistics
- Coordination and information meetings
- Travel arrangements

SAO did not produce any stand-alone formal documents as such during the period of performance. Analyses, error budgets, area vs. energy plots, and requirements were developed and documented as informal documents, particularly by Bookbinder, Cohen and Podgorski. These were distributed in a timely way as attachments to e-mail messages. The Constellation-X Top Level Requirements document and its companion Flow Down Requirements document are still in process and will, in any event, be released as project documents.

